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Improving information problem solving skills in Secondary Education through embedded instruction

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Abstract

This empirical study consists in an investigation of the effects, on the development of Information Problem Solving (IPS) skills, of a long-term embedded, structured and supported instruction in Secondary Education. Forty secondary students of 7th and 8th grades (13 to 15 years old) participated in the two-year IPS instruction designed in this study. Twenty of them participated in the IPS instruction, and the remaining twenty were the control group. All the students were pre- and post-tested in their regular classrooms, and their IPS process and performance were logged by means of screen capture software, to warrant their ecological validity. The IPS constituent skills, the web search sub-skills and the answers given by each participant were analyzed. The main findings of our study suggested that experimental students showed a more expert pattern than the control students regarding the constituent skill 'defining the problem' and the following two web search sub-skills: 'search terms' typed in a search engine, and 'selected results' from a SERP. In addition, scores of task performance were statistically better in experimental students than in control group students. The paper contributes to the discussion of how well-designed and well-embedded scaffolds could be designed in instructional programs in order to guarantee the development and efficiency of the students' IPS skills by using net information better and participating fully in the global knowledge society.

Keywords: information problem solving (IPS), World Wide Web, embedded instruction, scaffolding, Secondary Education.

1. Introduction

Nowadays, the World Wide Web (WWW) has become one of the most important information sources in both personal and academic life. Students in Secondary Education use the Internet widely for both leisure and school assignments; however, it is a widely accepted fact that the complex cognitive activities involved in the processes of gathering and processing information from the web are not instinctively acquired (Puustinen, Volckaert-Legrier, Coquin, & Bernicot, 2009; Wood, 2009). Secondary students have serious difficulties in such skills as identifying the information needed, searching, locating and processing information from the web (Wallace, Kupperman, Krajcik, & Soloway, 2000). To overcome this problem, educational institutions have the duty to instruct their students explicitly and extensively, since those skills are amenable to improvement through instruction (Willey et al, 2009). The main goal of this study is to analyze the effect of a long-term embedded, structured and supported instruction on the development of students' information problem skills. To accomplish this goal, in the next sections, we will first describe the concept of Information Problem Solving process and highlight the students' difficulties in developing it. Next, we will revise previous studies on effective design of instructional support in IPS processes and their limitations by means of an analysis of how our study plan may tackle and overcome these limitations by helping students to develop efficient IPS skills. Finally, we will formulate the research questions that guide our study.

1.1. Information Problem Solving

Gathering and processing information from the web involves complex cognitive activities and requires from individuals to identify information needs, locate information sources, extract and organize information from each source, and synthesize information from a variety of sources. This set of interrelated abilities is referred to as information seeking (Marchionini, 1995; Wallace et al., 2000; Wilson, 1999), Information Literacy (American Library Association, 1998; Shapiro & Hughes, 1996; UNESCO, 2006) or Information Problem Solving (Eisenberg & Berkowitz, 1990; Land & Greene, 2000; Moore, 1995; Wolf, Brush, & Saye, 2003).

Different models have described the information problem-solving (IPS) process as it can be segmented into several sub-processes (Brand-Gruwell, Wopereis, & Vermetten, 2005; Gerjets & Hellenthal-Schorr, 2008). As summarized by Gerjets, Kammerer, and Werner (2011), a collection from several existing models yields five important processes: 1) an information problem is defined, 2) normally, a search engine (e.g., Google) is selected, where a query with search terms is entered and sent off. Subsequently, a ‘search engine result page’ (SERP) with a list of search result links is retrieved to the user, 3) available search results are scanned, evaluated and selected for further inspection. This evaluation of search results is based on the information that the corresponding webpages contain (e.g., titles, summaries, and uniform resource locators, URLs), 4) after accessing a selected webpage, the information is scanned, evaluated with regard to its relevance for the search goal, and in case of relevance, information is extracted for further processing, 5) the information from different webpages is integrated towards a solution of the information problem.

Researchers agree that all these processes are not instinctively acquired by students, instead they are processes which need to be developed (Puustinen et al., 2009; Wood, 2009). This has become progressively more important with the increase of technology-enhanced learning and Information and Communications Technology (ICT) based resources which require more sophisticated search processes (Walraven, Brand-Gruwel, & Boshuizen, 2008); however, secondary students possess limited online information and critical evaluation skills (Landbook & Probert, 2011), and face many problems when exposed to an IPS task.

Different studies have already reported that teenagers struggle in the development of the IPS processes. These studies show that teenagers have difficulties in developing the different cognitive skills involved in solving an information problem. Among the difficulties highlighted by researchers we summarise the next five ones:

1) *Defining the problem*. Teenagers tend to have problems with ‘formulating questions’ (Wallace et al., 2000), ‘activating prior knowledge’, ‘clarifying task requirements’ and ‘determining needed info’ (Walraven, Brand-Gruwel, & Boshuizen, 2009). Most of them start searching immediately without exploring the topic, planning the search or thinking about the task (Fidel et al., 1999).

2) *Searching for information*. Most problems in the constituent skill ‘searching for information’ occur with sub-skills ‘specifying search terms’ and ‘judging search results’. Teenagers do not always know which search terms to use (Badilla-Quintana, Cortada-Pujol, Riera-Romaní, 2011; Bilal, 2000; Large & Beheshti, 2000; MaKinster et al., 2002; Wallace et al., 2000).

3) *Scanning information*. Teenagers have trouble separating reputable and questionable materials, and have problems with selecting and judging information (Lorenzen, 2002). They use information that could answer their question, even if the site were from a commercial source and not intended for science assignments (Fidel et al., 1999).

4) *Processing information*. Young searchers rarely take the time to read a site in-depth (Walraven et al., 2009). They also tend to judge processed information by looking for words they expected to find (Wallace et al., 2000).

5) *Organizing and presenting information*. Brand-Gruwel et al. (2005) mentioned that experts and novice searchers spend a similar amount of time on this phase, but experts focus their attention more on the formulation and reformulation of the problem. Probert (2009) pointed out that secondary students simply ‘copied and pasted’ their answers when using digital information in their assignments.

Considering all these difficulties, it is increasingly recognized that explicit IPS instruction is needed to achieve an adequate level of IPS expertise (Johnston & Webber, 2003; Larkin & Pines, 2005; Walton & Archer, 2004; Brand-Gruwel & Gerjets, 2008). Researchers also highlight that IPS instruction should be well-designed and well-integrated in the curriculum. This is precisely the focus of this research, namely the effect of well-designed and embedded instruction across secondary curriculum.

1.2. Instructional Support in Secondary Education

One of the main instructional principles used in our study is that IPS skills might be acquired embedded within a relevant and meaningful context and not through isolated assignments (cf. Kuiper, Volman, & Terwel, 2008).

Many effective embedded instruction research studies have been conducted in Primary Education (i.e., De Vries, et al., 2008; Pritchard, & Cartwright, 2004; Hoffman, Wu, Krajcik, & Soloway, 2003; Kuiper et al., 2008; Spink, Danby, Mallan, & Butler, 2010; Wang, Ke, Wu, & Hsu, 2011). However, embedded instruction studies in Secondary Education are scarce (i.e., Badilla-Quintana et al., 2011; Britt & Aglinskas, 2002; Raes, Schellens, De Wever, & Vanderhoven, 2011; Walraven et al., 2010). Most IPS instruction in Secondary Education is implemented as separate courses, loosely connected to the curricular contents (i.e., Colaric, 2003; Feddes, Vermetten, Brand-Gruwel, & Wopereis, 2003; Gerjets et al., 2008, Lazonder, 2001; Sanchez, Wiley, & Goldman, 2006; Stadler & Bromme, 2008; Walton & Helpworth, 2011).

In order to design the main educational guidelines of embedded instruction of IPS skills in Secondary Education, our study starts from previous studies on embedded instruction conducted in secondary classrooms. Their contributions and limitations are presented below together with our plan on how to overcome the latter.

Badilla-Quintana et al. (2011) carried out an ITC Project in Elementary and Secondary Schools in Spain, which consisted mainly in providing technological equipment to the participating centres such as digital interactive whiteboards, audiovisual systems, scanners, computers, laptops, printers and a series of connectivity points to the Internet, as well as other didactic resources. Although the project reported improvements in the participants' knowledge and control of computers and operating systems, and in their information management skills through the Internet (finding, assessing and using the information), the lack of systematic instruction on IPS skills did not help students to maximize their digital literacy. These results are similar to other reports that conclude that students do not always master more knowledge of basic ICT skills in spite of the increasing presence of ICT in the world and in schools (Kaminski, Switzer, & Gloeckner, 2009; Strømsø, Grottum, & Lycke, 2004).

The study of Britt and Aglinskas (2002) analyzed the impact of embedded instruction –scanning and processing information while searching– on teenagers and concluded that the results were effective in web searching processes; however the instruction received only focused on the sources and the information rather than on other constituent skills considered in IPS (Brand-Gruwel et al., 2005).

Another interesting embedded intervention in secondary school classrooms was carried out by Raes et al. (2011). This was a large scale intervention with the purpose of improving domain-specific knowledge and metacognitive awareness of the students' IPS processes by means of scaffolds. The study measured the IPS skills by means of self-reporting after the IPS task performance. The findings showed an overall improvement of the students' performance. However, the authors also reported that one of the limitations of their study was the lack of studying deeply the learning processes during the task performance, which could have given more insight into the IPS skills performed and could have shed more accurate conclusions on the effect of scaffolding during the learning process.

Other research studies have faced the issue of how to help students to transfer IPS skills to other contexts. Walraven et al. (2010) designed and evaluated two educational programs to foster IPS skills in secondary classrooms in order to test two transfer theories. Their study reveals the need of more research that guarantees the *transfer* of IPS processes to other subjects or areas. Other studies support this conclusion (i.e., (Brand-Gruwel, et al., 2010; Ten Dam & Volman, 2004).

In addition, most IPS studies are short-term studies and the authors admitted that further *long-term* studies should be developed in order to see whether the positive effects of the instructional process were maintained over time (Braten, Strømsø, & Salmerón, 2011; Walton et al., 2011).

Furthermore, Wopereis, Brand-Gruwel and Vermetten (2008) argued the need to study the design of effective IPS instruction. In their study these authors claimed that effective IPS instruction should take into account the following two instructional principles: a) IPS instruction should be embedded in *authentic learning tasks* in which learners aim the integration of knowledge, skills, and attitudes necessary for effective 'overall' task performance, and b) the instruction should design effective *scaffolds* to guide the development of the IPS process; in this line, worksheets accompanied with driving questions, which guide and direct students during the problem solving process, are emphasized as effective in IPS instruction.

In view of the conclusions from previous studies on IPS instruction this study aims to prove that an efficient design, implementation and analysis of IPS instruction in Secondary Education should take into account embedded, structured and supported variables. Our study integrates these three variables in the design of the instruction implemented and evaluated in our research work. It can briefly be described as: 1) *embedded* in a meaningful and real context (classroom) spanning two academic years with a view to developing IPS skills and task performance, and learning from the web, 2) *structured* by designing web-based activities which follow the WebQuest structure (Dodge, 1995), and 3) *supported* by providing scaffolds in the several skills needed to tackle information problems. A more extensive explanation of the instruction designed in our work can be found in section 2.3.1.

1.3. Research questions

The purpose of our research is to study the effect of an embedded, structured and supported IPS instruction on IPS skills and task performance. We hypothesize that students who participated in the integrated instruction on IPS will execute the IPS skills and its constituent skills more adequately and intensively.

The research questions of our study are the following three:

1. What are the differences between students who participated in the embedded IPS instruction and students who did not participate, regarding the development of IPS skills and sub-skills during the resolution of an IPS task? Do the instructed students show a more expert websearching pattern than the non instructed students?

2. Do the instructed students obtain a better task performance (in terms of results) than that of non-instructed students?

3. Is there a correlation between the process (constituent skills and sub-skills) and the task performance in the IPS tasks executed by the participants?

2. Method

2.1. Participants

Forty students participated in this study. All of them were students in year 7th and 8th (13 to 15 years old), Secondary Education. The students belonged to three urban schools in the city of Lleida (Spain).

Participants belong to a larger sample that, in turn, belongs to a larger study that aims to promote digital literacy on secondary students by using the internet regularly in the classroom. This larger study was a 6-year research and development project (R+D project) and took into account reliability issues in the process of selecting the schools and designing the research study.

2.2. Design and procedure

The nature of this study was quasi-experimental and was set up according to a pre-test post-test control-group design. In order to maintain the natural setting of the classroom, one school was established as the control group, while the other two acted as the experimental group. From the 40 participants, 20 of them constituted the control group, and the remaining 20 were randomly selected from both experimental schools and constituted the experimental group.

In order to minimize possible variables which could affect the reliability of participants' selection in the experimental-control group, the following variables were taken into consideration and hence monitored: socio-demographic, psycho-pedagogical and task performance variables. As regards the *socio-demographic* variable, the three schools are comparable since they have similar features: school type (public), socio-economic status of school students (middle class), and school location (urban). Regarding the *psycho-pedagogical* variable related to the study reported in this paper, the schools did not participate in any teaching innovation project involving the use of ICT. Furthermore, all the students were assessed by means of a pre-test focusing on their initial level of performance in the resolution of an IPS task -*task performance* dependent variable (see section 2.3.2 for an extensive description of dependent variables). A *t*-test revealed no statistically significant differences between the two experimental schools (school 1: $N = 9$, $M = 43.79$, $SD = 30.29$; school 2: $N = 11$, $M = 24.06$, $SD = 25.99$; $t(18) = -1.559$, $p = .139$). So from now on, in our study we will consider the two experimental schools as an experimental group.

The quasi-experimental design process had three phases: 1) a pre-test was conducted on control and experimental students at the beginning of the research project; 2) after the pre-test, the students in the experimental group followed the embedded IPS instruction in the secondary curriculum for two academic years and 3) after these two years the post-test was conducted on all students.

2.3. Materials

2.3.1. Intervention: characteristics of the IPS instructional process

Over two academic years, the students in the experimental group learned the contents of the curriculum areas by means of the teaching methodology routinely used by their teachers, and they were also engaged in an IPS Web-based learning environment embedded in the curricular contents. The control group did not receive that specific IPS instructional process.

The IPS web-based activities of the instructional process were designed by teachers and researchers, and were devoted not only to training IPS skills, but also to learning curricular contents. The activities belonged to the following areas: technology, maths, science and social science (for samples of those activities, the reader can click on the following link: http://contic.udl.cat/en/resources/secondary). Each activity consisted in an authentic learning task within approximately 4 sessions of 60 minutes each. The experimental condition students participated in 9 web-based activities (36 hours in total) during the first year of the instructional process, as well as 6 web-based activities (24 hours in total) during the second year. Thus, they received as many as 60 hours of instructional process.

The students worked in pairs during the instructional process to solve the IPS activities collaboratively. Walraven et al. (2008) reported and analysed several studies dealing with instructional support in IPS, and pointed out that the collaborative nature of the instruction was one of the key instructional variables that contributes to improving certain sub-skills, such as ‘formulating questions’ and ‘activating prior knowledge’. These are both critical skills included in the constituent skill ‘defining the problem’. Collaboration encourages students to articulate their thoughts, and these verbalizations of one’s own thoughts might have a positive impact on problem solving (Teasley, 1995). In addition, peer interaction urges users to negotiate the suitability of search strategies and decisions, and to give the opportunity for users to critically observe each other’s actions, which may facilitate early detection and correction of potential mistakes (Lazonder, 2005; Okada & Simon, 1997).

The key instructional principles that guided the web-based activity instructional process were the following three: i) *embedding* the IPS skills in authentic curricular activities, ii) *structuring* the students’ problem solving and iii) *supporting* the students problem resolution with specific scaffolds. In the following paragraphs we will expound the characteristics of the intervention.

i) One of the key instructional principles that guided the instructional process was the ***embedding*** of the instruction to construct curricular knowledge in a real context. The design of our instructional process enhanced meaningful knowledge construction (De Vries et al. 2008), promoted transferability of IPS to solving problems in other contexts (Brand-Gruwel et al., 2009) and was due within a period of time long enough to acquire and consolidate the web skills trained. In view of these important pedagogical considerations of IPS instruction, our project was designed to practise contents of four different curricular disciplines and was implemented during two academic years.

ii) The second key instructional principle that guided the instructional process was ***structuring*** the students' problem solving by means of using a WebQuest approach (Dodge, 1995). This approach consists in giving students an authentic problem to solve using web resources. We chose a WebQuest methodology because it fitted into the main IPS instructional principles of our study. Below, we will point out briefly the four pedagogical principles for using a WebQuest approach in our study:

a) WebQuest methodology is grounded on problem-based learning methodology. This methodology focuses on a real learning problem which students need to solve by integrating knowledge, skills and attitudes, and using our resources.

b) Students have to search the web for a well-defined objective. This principle sets up a good scenario to embed explicit IPS instruction in order to improve the web searching, web selecting information and organisation of the web information.

c) A WebQuest provides a well-defined structure for the learning processes (Zheng, Perez, Williamson, & Flygare, 2008). A well-designed WebQuest usually contains six stages: 1) introduction, 2) task, 3) information sources, 4) description of the process, 5) performance evaluation, and 6) conclusion. This structure allows us to introduce an IPS instruction in a natural way.

d) WebQuest methodology promotes knowledge construction through the critical and creative use of web resources. However, in a typical WebQuest the student is provided with a pre-selected list of websites, so that the use of the Web is quite limited (Caviglia & Ferraris, 2008). For this reason, all the web-based activities of our large project were enriched by a wide set of scaffolds to help students search, analyse and organise web information to successfully solve a digital problem (Pifarré, Sanuy, Vendrell, & Gòdia, 2008), further explained below.

iii) Finally, the third key principle of our intervention was ***supporting*** with specific IPS scaffolds the students' problem solving. Supporting multiple students in a technology-enhanced classroom requires readjusting the notion of scaffolding (Luckin, Looi, Chen, Puntambekar, & Stanton Fraser, 2011; Puntambekar & Kolodner, 2005). In this vein, scaffolding to support IPS processes is gaining recognition as an important instructional scaffolding method in computer-based learning environments (Bannert & Reimann, 2011) in complex classrooms (McNeill & Krajcik, 2009; Puntambekar et al., 2005; Tabak, 2004).

Scaffolds are defined as temporary supporting structures to promote student learning of complex problem solving or reasoning (Bransford, Brown, & Cocking, 2000; McNeill et al., 2009). Within technology-enhanced learning environments, these can be displayed on screen at certain times in the learning process, because the students do not usually execute their IPS skills spontaneously (Bannert et al., 2011). Educational research provides evidence that it is possible to improve individual learning in a scaffold-based technology environment to activate their cognitive processes (Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008).

In our work, the web-based activities designed give guidance and specific scaffolds to learn skills in the main IPS constituent processes, namely 1) defining the information problem, 2) searching for information, 3) scanning and processing information, and 4) organizing and presenting information. We embedded these IPS skills in the WebQuest structure of all our activities. We presented these scaffolds by means of questions, worksheets (De Vries et al., 2008; Walraven, Brand-Gruwel, & Boshuizen, 2010, Wopereis et al., 2008), prompts (Morris et al., 2010; Stadtler & Bromme, 2008), pop-up messages, concept maps, simulations and templates (Pifarré, 2009). Fig. 1 presents an overview of the IPS scaffolds designed in the instructional process and some examples about how these scaffolds were displayed to the students. The IPS scaffolds were embedded in the whole learning task and gradually lost intensity as the instructional process progressed.

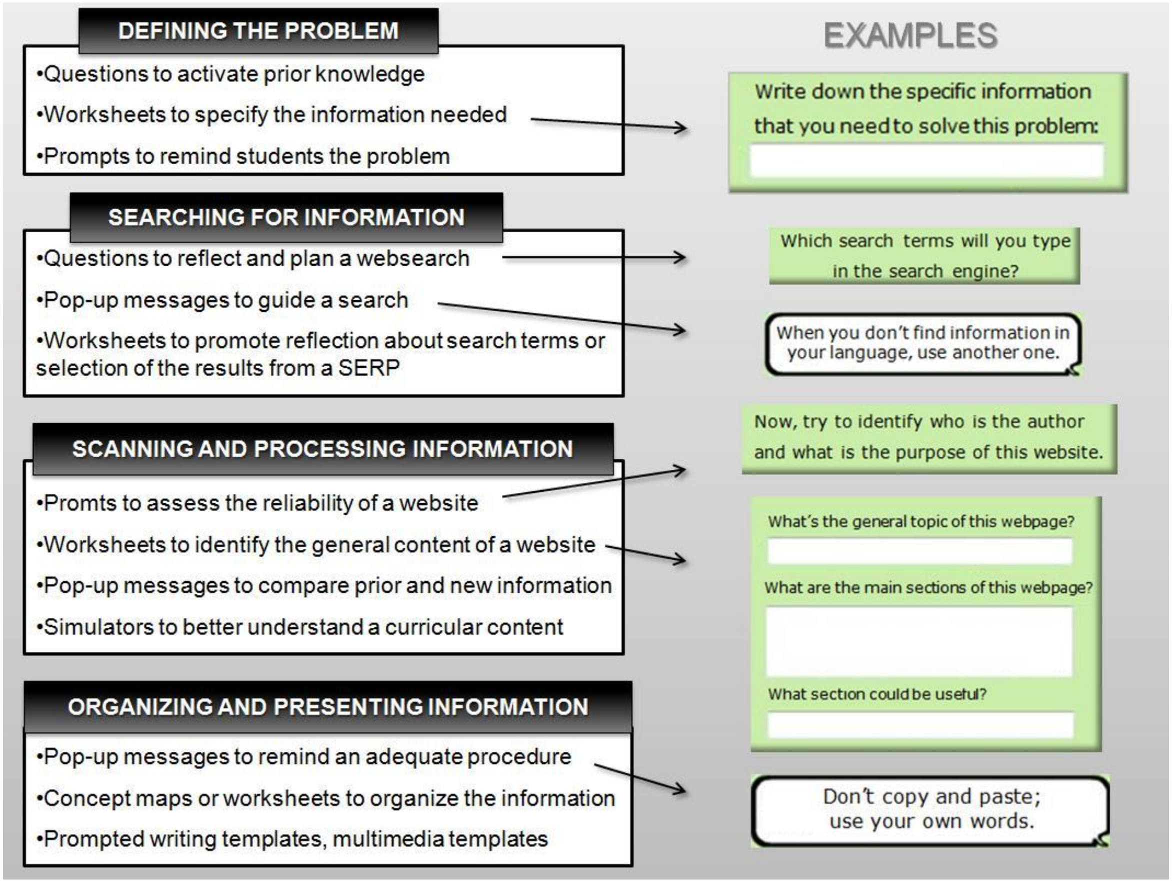

Fig. 1. Scaffolds of each constituent skill during the instructional process (adapted from Pifarré et al, 2008).

Fig. 2 presents an example of a scaffolded section of one of the web-based instructional activities, this activity was entitled: *Toxic waste management*. This activity presented the problem that a toxic liquid has been spilled on the street next to school and students had to try and solve it by using the information from the WWW. Students were guided along four steps: first, investigating the chemical characteristics of the liquid spilled; second, identifying good and bad decisions regarding packaging and storage of the chemical liquid; third, figuring out how to clear up the spilled substance, and finally, writing a report addressed to environment specialists that included all the details of their researching. (To access the entire activity, click on the following link: http://contic.udl.cat/exemples/Gestion_de_residuos_toxicos/inicio.htm).

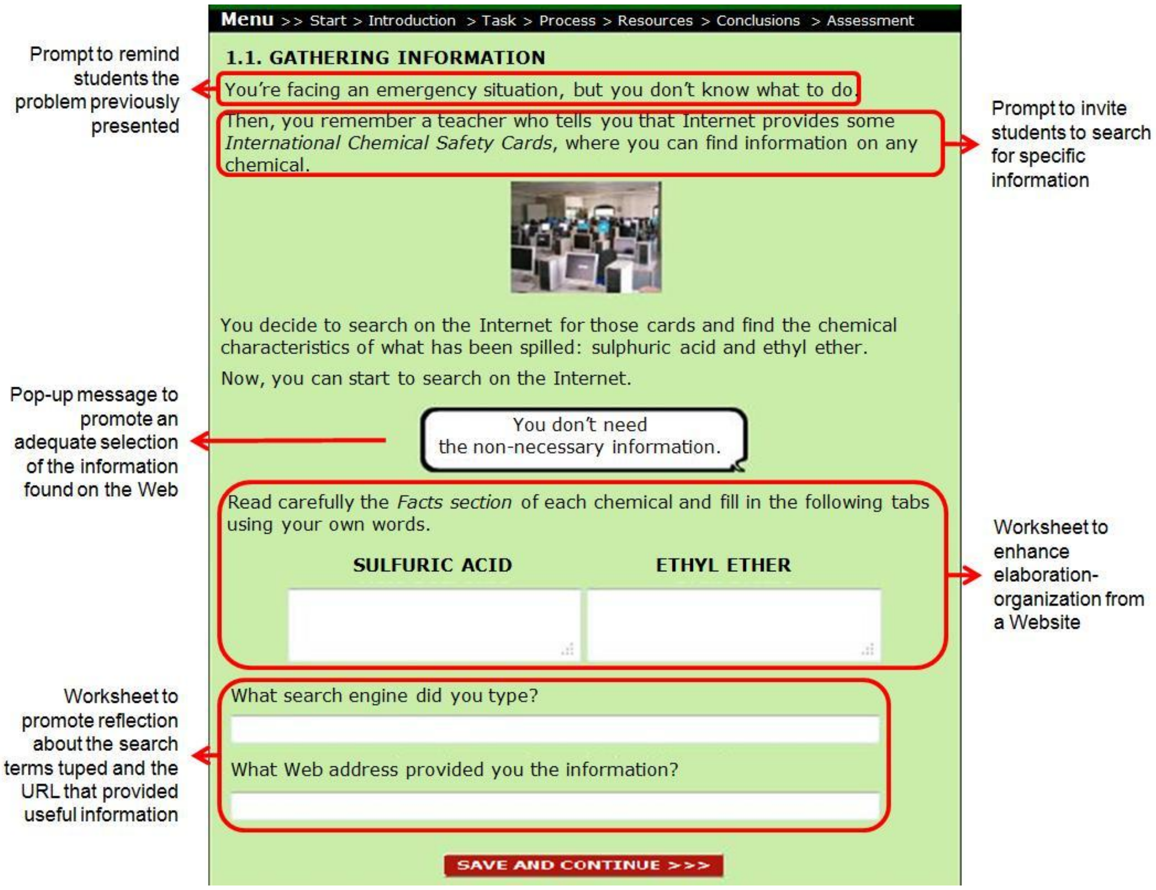

Fig. 2. A section of a web-based instructional activity and examples of scaffolds displays (translated from Spanish).

2.3.2. Pre- and post- tests

At the beginning of the first academic year and at the end of the second year, both control and experimental groups performed an IPS task as a test. Students solved the same IPS task during the pre- and post-test evaluation. They solved it individually and each IPS task took about 50 minutes. It was performed in the real context of the classroom in order to ensure *ecological validity* (Wopereis & van Merriënboer, 2011).

The IPS task was divided into two main parts. In part 1, participants were engaged in completing a concept map to collect information about planet Mars (physical characteristics, orography, atmosphere, climate, satellites). In part 2, participants had to accomplish three steps: 2.1) explaining, using information from the WWW, the conditions a planet must fulfil to make life possible on it, 2.2) describing the favourable and unfavourable conditions of Mars, and 2.3) writing a final essay that would answer the question of whether it would be possible to install a human colony on Mars, and, if so, what difficulties would have to be overcome, and why (Fig. 3).

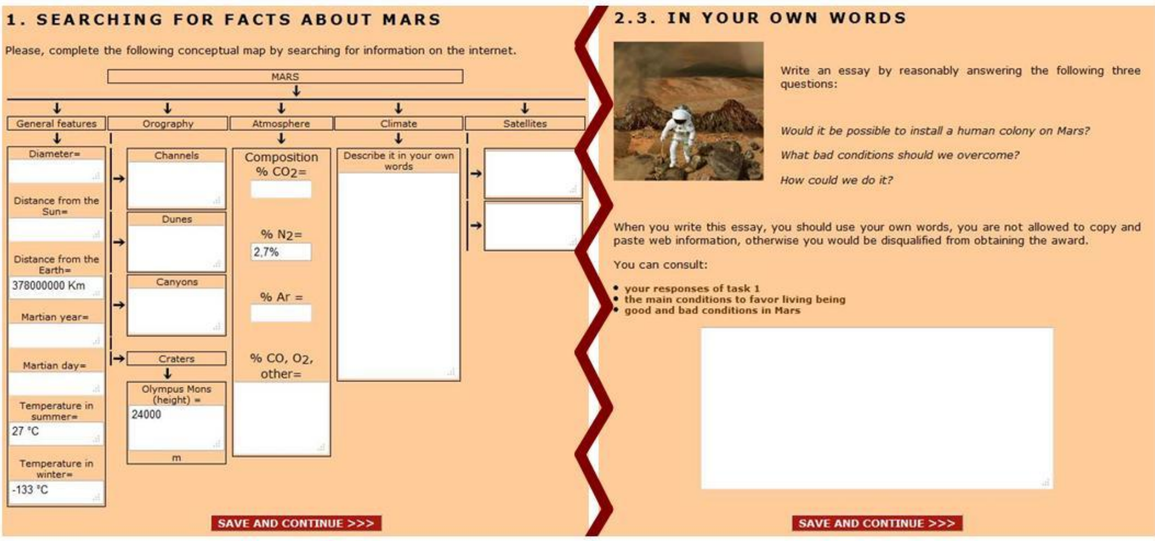

Fig. 3. Two different screenshots of the pre- and post-test task (translated from Spanish).

2.4. Data analysis procedure

Pre- and post- IPS tasks of each participant (N=40) were logged in by a screen capture software called CamStudio 2.0 in an attempt to record all the actions performed on the computer screen. The purpose of this recording was to obtain data on the problem-solving process based on an IPS task and to analyze both the process and the product performed by the participants during the IPS task in the real context of the classroom in an unobtrusive way. One logfile per student was obtained. A total amount of 80 logfiles were obtained (that is, 2 tests by 2 conditions by 20 students).

Each logfile was observed in detail and transcribed. Thus, a protocol was obtained from each logfile. Each protocol consisted of three main parts. The first part was devoted to the constituent skills and contained the following columns: time line, constituent skill performed and duration of the skill performed. The second part was devoted to the web search sub-skills and consisted in the following columns: search terms typed, appropriateness of the search terms, selected results, and appropriateness of the selected results. The third part of each protocol was about the product (task performance) and contained the following columns: students' answers, and correctness of the answers.

Two raters, familiar with both the search task and the materials, coded 15% of all the protocols. Interrater reliability computed on this subsample of protocols yielded a Cohen's Kappa higher than .80. One rater scored the remaining protocols.

As a result of the data analysis of the pre- and post-tests, different dependent variables were obtained for the IPS process (*constituent skills* and *sub-skills*) and for the IPS product (*task performance*). Table 1 shows every variable together with their measurement. In the next sub sections, the dependent variables analyzed in this study are described.

Table 1. *Dependent variables and their measurement*

Dependent variables		Measurement
Process	Constituent skills: 1. - Defining the problem 2. - Searching for information 3. - Scanning and Processing Info 4. - Organizing and Presenting Info	Number of times performed
	Web-search sub-skills: 5. - Search terms 6. - Selected results	Appropriateness of the search terms and the selected results
Product	7. - Task performance	Answers' correctness score

2.4.1. Dependent variables related to Constituent skills

The first part of each protocol obtained refers to the constituent skills: 1) defining the problem, 2) searching for information, 3) scanning and processing information, and 4) organizing and presenting the information (Brand Gruwel et al., 2005; Pifarré & Argelagós, 2008). Each constituent skill was coded, therefore the *number of times* spent on each constituent skill was recorded. Short descriptions of these constituent skills can be seen in Table 2.

Table 2. *Coding scheme of constituent skills*

Constituent skills	Short descriptions
Defining the problem	The student is analysing the demand in the IPS task (the computer screen shows the webpage of the assignment demand). (S)he is not typing anything on it.
Searching for Information	The student is searching for the information on the web: accessing a search engine, typing search terms on it, or selecting results from a SERP (the computer screen shows the search engine or the SERP).
Scanning and Processing Information	The student is scanning and processing the information in a website.
Organizing and Presenting Information	The student is typing an answer in the IPS task.

2.4.2. Dependent variables related to Web-search sub-skills

The second part of each protocol retrieved refers to the following sub-skills: *search terms typed* and *selected results*. Two reasons drove us to only consider those sub-skills: first, several studies have reported on the relationship between the search terms appropriateness and the selected results evaluation with expertise in websearching (Lazonder, 2000; Monereo, Fuentes, & Sánchez, 2000), and also with the quality of the task performance, i.e., the product (Gerjets, et al., 2011; Ladbrook & Probert, 2011; Tu, Shih, & Tsai, 2008; Willey et al., 2009) and second, the kind of data obtained (that is, a logfile of the actions performed by each student) allows observing specific actions made by the subject with the mouse or keyboard (for example: search terms typed, results selected by clicking on them, number of times they visit a website, etc.).

Search terms. Each search-term was transcribed verbatim and so each protocol showed each search term typed during the IPS tasks. Additionally, the appropriateness of each search-term typed scored as 'appropriate' (1 point) or 'inappropriate' (0 points). This appropriateness did not take into account only the number of keywords typed (Tu et al., 2008), but also considered their context and their demand, as suggested by Kuiper et al (2008). For example, the search-term 'diameter of Mars' typed in Google when the participant was searching to answer the demand *Mars' diameter,* was considered as 'appropriate', whereas 'conditions of Mars to life' when the demand was *conditions that make a planet suitable for life* scored as 'inappropriate' because that search-term refers only to Mars while the demand refers to any planet. In addition, an appropriateness score was calculated as a percentage considering the number of search terms used and the number of appropriate search terms.

Selected results. Each result that was selected from a SERP by each participant was gathered and so each protocol showed all the selected results during each IPS task.

Furthermore, each selected result scored as 'appropriate' or 'inappropriate'. The criteria taken into account to evaluate each search result were both *usability* and *reliability* (Gerjets et al., 2011; Rouet, Ros, Goumi, Macedo-Rouet, & Dinet, 2011; Walraven et al. 2008; Willey et al., 2009). A selected result was considered 'usable' when its content (title, description, URL, and other information available in the SERP) followed the question to be answered, and was considered as 'reliable' when the author or source was plausible. Each selected result scored as 'appropriate' (1 point) when it was both usable and reliable, and as 'inappropriate' (0 points) when it was either not usable or unreliable. Again, an appropriateness score was calculated as a percentage considering the number of total selected results and the number of correct ones.

2.4.3. Dependent variable 'Task performance'

Students' answers also scored in a binary fashion as either 'correct' (1 point) or 'incorrect' (0 points). The maximum score possible was 16 points, and such a correctness score were calculated by considering the percentage between the number of correct answers given and the maximum number of points to be obtained.

2.4.4. Statistical analyses

SPSS version 18.0 software was used for the analysis of the data obtained and repeated measures ANOVA were calculated for each dependent variable, with confident intervals between 95% and 99%, in order to compare the effect of the IPS embedded instruction on each dependent variable in experimental and control conditions. In addition, the Pearson correlation coefficient was used to determine the relationship between constituent skills, sub-skills and task performance, with a 95% and 99% confidence intervals.

3. Results

In this section, we will first show the results obtained in the analyses of the pre-test for the experimental and control groups, in order to identify possible differences. Then, we will show the results obtained by repeated measures ANOVA to compare pre-post experimental condition in order to answer the first and second research questions of our study. Finally, we will show the correlation analyses between the variables to give an answer to the third research question of our study.

3.1. Analyses of the pre-test

As seen in table 3, there are no significant differences between experimental and control groups in the pre-test as regards the dependent variables related to the *sub-skills*, both ‘search terms’ and ‘selected results’, as well as the dependent variable related to *constituent skills* ‘organizing-presenting information’.

Closer analysis reveals that the *constituent skills* performed by the experimental and control students in the pre-test, *t*-test showed significant differences in the following skills: ‘defining the problem’, ‘searching for information’, ‘scanning-processing information’. In addition, the dependent variable ‘task performance’ also revealed differences. It is worth noting that descriptive statistics showed that experimental students obtained lower means in these variables compared with those obtained by the control group students.

Table 3. *Dependent variables related to constituent skills, sub-skills and task performance in the pre-test. Means (in braquets, SD), t and p values.*

Dependent variables	Experimental group		Control group		*t*	*p*
Constituent skills						
1.- Defining the problem	27.2	(9.6)	36.4	(6.9)	3.494	.001
2.- Searching for info	18.1	(8.3)	26.9	(10.9)	2.890	.006
3.- Scanning-processing info	34.7	(17.6)	48.2	(11.3)	2.894	.006
4.- Organizing-presenting info	15.8	(11.3)	17.3	(6.0)	.542	.592
Sub-skills						
5.- Search Terms (score)	52.9	(23.2)	54.5	(20.4)	.229	.820
6.- Selected Results (score)	61.4	(23.1)	71.3	(18.1)	1.504	.841
7.- **Task performance**	32.9	(28.7)	49.7	(20.1)	2.140	.039

Constituent skill ‘organizing-presenting information’ and sub-skills were performed by both groups of students without significant differences. Differences found in some constituent skills’ frequencies and in task performance will be taken into account during the interpretation of the results in the following sections, in order to guarantee the validity of the results on the impact of the IPS instructional process.

3.2. Constituent Skills: Pre-post analyses

As shown in Table 4, during the post-test, experimental group invested a higher number of times on the constituent skills ‘defining the problem’ and ‘organizing and presenting information’ during the IPS task resolution. By contrast, the control group invested more number of times on the skills ‘searching for information’ and ‘scanning and processing information’ in comparison with the experimental group. Despite of the fact that the control group already showed a significant higher frequency in the pre-test , the results revealed a different proportion between the number of times performed on the skills ‘search for information’ and ‘scanning and processing’ by experimental and control groups during the post-test. Although both groups invested a higher number of times during their post-test on ‘scanning and processing’ than on ‘searching’, the proportion of the experimental group more than doubled that of the control group, as shown in Table 4. Although repeated measures ANOVA did not show significant differences on those means in terms of interaction with the independent variable, they revealed an encouraging trend, namely that the experimental students did not need to perform so many times the constituent skill ‘searching for information’ due to more efficiency (as demonstrated in the following sub sections) during the searching sub-skills, such as ‘search terms’ typed in a search engine and ‘selected results’ from a SERP.

Table 4. *Dependent variables related to constituent skills. Number of times performed during the IPS task. Means (in brackets, SD), F and p values.*

Dependent variables related to constituent skills	Experimental group				Control group				F values		
	Pre-test		Post-test		Pre-test		Post-test		Between-subjects	Within-subjects	Interaction
Defining the problem	27.2	(9.6)	44.1	(10.2)	36.4	(6.9)	38.4	(8.1)	.581	36.199**	22.498**
Searching for Info	18.1	(8.3)	28.0	(9.2)	26.9	(10.9)	34.7	(14.4)	8.540**	16.090**	226
Scanning-Processing Info	34.7	(17.6)	61.8	(17.3)	48.2	(11.3)	63.0	(19.6)	3.234	39.206**	3.414
Organizing-Presenting Info	15.8	(11.3)	28.4	(11.0)	17.3	(6.0)	25.0	(7.9)	.191	24.555**	1.453

* $p < .05$; ** $p < .01$.

As a conclusion of this sub-section, during the post-test, students from the experimental group invested significantly more times on the skills ‘defining the problem’ and also followed the general trend of performing more times ‘organizing and presenting information’ in comparison with the control group. In addition, experimental students performed more times the ‘scanning and processing’ skills than the ‘searching’ skill. We can conclude that experimental group students used a more expert IPS pattern than control group students (Brand-Gruwel et al., 2005; Lazonder, 2000).

3.3. Sub-Skills: Pre-post analyses

This section analyzes the variables related to sub-skills ‘search terms’ typed in a search engine, and ‘selected results’ from the SERP retrieved by a search engine. These sub-skills belong to the constituent skill ‘searching for information’. A repeated measures ANOVA showed that the experimental group reached higher appropriateness’ scores in search terms typed and in selected results from the SERP, as can be seen in table 5 and in Fig. 4.

Table 5. *Dependent variables related to sub-skills: Search terms (ST) and Selected Results (SR). Means (in brackets, SD), F and p values.*

Dependent variables related to sub-skills	Experimental group		Control group		F values		
	Pre-	Post-	Pre-	Post-	Between subjects	Within-subjects	Interaction
ST (score)	52.89 (23.24)	87.12 (13.09)	54.48 (20.44)	56.27 (17.73)	9.255**	25.004**	20.268**
SR (score)	61.40 (23.09)	87.17 (11.26)	71.27 (18.12)	72.38 (9.89)	.446	13.304**	11.190**

* *p* < .05; ** *p* < .01

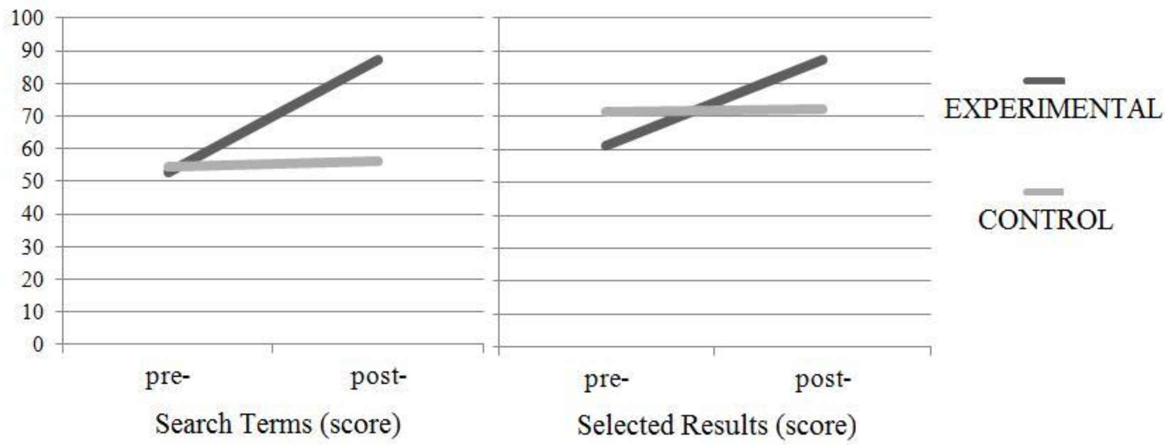

Fig. 4. Interaction between pre-post test and experimental-control condition regarding instructional process and the variables related to sub-skills *Search terms* and *Selected results.*

3.4. Task Performance: Pre-post analyses

The ANOVA results showed that participants of the experimental group performed their IPS tasks with a significantly higher level of correctness than participants of the control group, as can be seen in Table 6. We can conclude that after the intervention the experimental group was significantly more successful in the variable 'task performance' compared with the control group.

Table 6. *Dependent variable 'Task performance'. Means (in brackets, SD), F and p values.*

	Experimental group		Control group		F values		
	Pre-	Post-	Pre-	Post-	Between-subjects	Within-subjects	Interaction
Task performance	32.94 (28.72)	73.00 (21.02)	49.01 (20.06)	52.33 (16.37)	.108	34.994**	26.908**

* $p < .05$; ** $p < .01$

3.5. Correlation between Process and Product

Regarding the relation between the process and the product in all the students (experimental and control as a whole group, N=80) and regarding to post-test results, Person's correlations were calculated among the dependent variables related to constituents skills, web-search sub-skills, and task performance. Table 7 shows the relations among these variables.

Among the constituent skills, a high correlation was found between the skills 'defining the problem' and 'scanning-processing information' and also 'organizing-presenting information' in terms of number of times performed. In addition, the skill 'searching for information' correlated with the skill 'scanning-processing information'. Finally, the same correlation was found between 'scanning-processing' and 'organizing-presenting'. These results verify the results shown above. More frequency in 'defining the problem', more frequency in 'scanning-processing' and 'organizing-presenting', but not more frequency in 'searching'. More attempts in 'searching' would reveal poor search ability.

In addition, there was a strong relationship between the web search sub-skills: 'search terms' and 'selected results'. Furthermore, some of the constituent skills correlated with some web search sub-skills, as the following. There was a relationship between the number of times performed on 'defining the problem' and the appropriateness of the 'selected results'. Additionally, the number of times performed on 'organizing-presenting the information' correlated with the appropriateness of 'search terms' and 'selected results'.

Finally, the high level of task performance of the participants correlated with a high number of times performing the skill 'defining the problem' and 'organizing-presenting information'. A high level of task performance of correctness also correlated positively with the appropriateness scores of 'search terms' and the appropriateness of 'selected results'.

Table 7. *Correlation between process (dependent variables related to 'constituent skills' and 'sub-skills') and product (dependent variable 'task performance') regarding to post-test results.*

		Constituent skills				Sub-skills		
		Defining problem (number of times)	Searching for info. (number of times)	Scanning-processing info. (number of times)	Organizing-presenting info. (number of times)	Search terms (score)	Selected results (score)	Task performance
Constituent skills	Defining problem (number of times)	1.00	.15	.49**	.42**	.24	.35*	.38*
	Searching for info. (number of times)		1.00	.55**	.92	-.14	-.06	.06
	Scanning-processing info. (number of times)			1.00	.66**	.10	-.28	.23
	Organizing-presenting info. (number of times)				1.00	.36*	.51*	.33*
Sub-skills	Search terms (score)					1.00	.63**	.70**
	Selected results (score)						1.00	.58**
	Task performance							1.00

* *p* < .05; ** *p* < .01 (two-tailed)

4. Discussion

The purpose of this study was to analyze the effect of a long-term embedded, structured and supported IPS instruction in solving authentic problems of different curricular disciplines undertaken by secondary students. To be more specific, the study aimed to determine the effect of instruction on the development of IPS skills and the improvement of the students' task performance. Frequencies of constituent skills on a pre- and post-test were calculated to measure differences between students who participated in the embedded IPS instruction and those who did not. In addition, the sub-skills performed were also analysed and compared. Our hypothesis was that students who participated in the long-term embedded IPS instruction to better solve problems on curricular contents would perform the IPS process and the accompanying constituent skills more adequately and intensively than students who did not participate in the instruction. Moreover, our study also aimed to verify the impact, if any, of improving the IPS skills and task performance on the students' learning results.

Regarding the constituent skills, the instruction might have a positive and significant effect on the skill 'defining the problem'. After attending the IPS instructional process, experimental students performed that skill more frequently. Research carried out by Brand-Gruwel et al. (2005) reveals that experts spend considerably more time on defining the problem than novices. Similarly it could be expected that 'more instructed (or experienced)' students also use more time to examine problem information (Wopereis et al., 2008). It could be remarked that the instructional process designed in this research supported extensively and thoroughly those IPS skills related with 'defining the problem' by means of driving questions to activate the prior knowledge and determine appropriate search terms, and worksheets to specify the information needed. According to Pejtersen and Fidel (1999), an adequate understanding of the problem is needed in order to perform an appropriate use of search terms. Thus, we can state that the IPS instruction designed in our study succeeded in promoting IPS when applied to the skill ‘defining the problem’.

In addition, the results of our study also showed interesting differences between experimental and control groups as regards the constituent skills ‘searching for information’ and ‘scanning and processing’. In the resolution of the IPS task, the proportion between the number of times performed on the skill ‘searching for information’ and ‘scanning and processing’ by each group in the post-test varied. Although both groups performed the skill ‘scanning and processing information’ more times than the skill ‘searching for information’, the proportion is higher (more than doubled) in the experimental group. This trend reveals that the students from the experimental group could search more efficiently, needed less attempts and so they could invest more effort in ‘scanning and processing the information’. This is also reflected in the students’ task performance, as discussed below.

As regards the sub-skills, the experimental group obtained significantly higher appropriateness scores in ‘search terms’ typed and ‘selected results’ from the SERP, in comparison with the control group during the post-test. The experimental group could search more efficiently and so could perform more frequently other important skills, such as ‘defining the problem’, ‘scanning and process information’, or ‘organizing and presenting’ it. These results are in line with those reported by Monereo et al. (2000), who found that experts use more elaborate search terms and carry out more selective selection of the results from a hit list. Furthermore, Landbook and Probert (2011) suggested that improving on deciding which sites to visit – in other words, on selecting results–, would not only increase efficiency but also effectiveness on their performance. In the same vein, Lazonder (2000) reported that experts perform in a better way the location of the site than novices. Students belonging to the experimental condition show a more expert websearching pattern than the control group ones. These results show that the embedded, structured and supported IPS instructional process might have a positive effect in developing skills related with ‘searching for information’. During the resolution of the instructional web-based activities designed in this project, experimental group students were scaffolded to reflect on the search terms to type in order to find specific information and assess the results retrieved by them. Besides, scaffolds in the form of prompts and messages guided students explicitly to reflect and evaluate the results retrieved by the SERP before selecting them.

Furthermore, the IPS instruction also might have a positive effect on experimental students’ task performance. Statistically, control group students scored significantly lower results than the experimental group. This is in line with findings by Gerjets et al. (2011), whose study showed that stimulating learners to engage in web-search skills could improve their web-search performance. In our view, all the scaffolds provided during the instruction and especially those related to ‘scanning and process the information’ might help students to construct knowledge in a more efficient way. The IPS instructional process consisted in designing both specific worksheets to help students analyze the general content of a website and prompts to encourage students to read and process its information.

Finally, the results of the study described in this paper coincide with previous findings by Brand-Gruwel et al. (2009), who pointed out that the constituent skills and sub-skills involved in IPS are highly related between them. For example, defining the problem in depth could have contributed to searching the information better, and to select results from a SERP in an appropriate way (and, consequently, to make less attempts in the skill ‘searching for information’); specifying the search terms could have made it easier to select an appropriate result; scanning and processing the information carefully could have enabled a better answer to the assignment. These relationships were verified statistically in our study. Furthermore, the close relationship between the variables of the process (constituent skills and sub-skills) and the variables of the product (task performance) might lead to conclude that the students' abilities of 'search terms' typed and the 'selected results' from a SERP are influential factors among search strategies to their task performance on the web, as stated by Tu et al. (2008) and Gerjets et al. (2011). Therefore, an important part in IPS instruction is helping students' search skills.

The present study is an attempt to give an insight into the design and implementation of long-term and well-integrated IPS instruction in Secondary Education curriculum. Our results showed the effectiveness of the long-term embedded, structured and supported instruction to develop students' IPS skills and task performance. However, our results must be interpreted carefully due to the following three limitations. First, the sample considered for this study –20 participants in each condition– might be a slightly limited segment to generalize the results to a wider segment; on the other hand, those results outline an encouraging path in the field of instructional design in IPS. Second, we are aware that the results presented in this study are not exclusively accountable to the IPS instructional process designed, implemented and assessed in our study, but also to another key educational variable that was not recorded in our research –the teacher. Further studies could then take teachers into consideration as human scaffolds in orchestration with other kind of scaffolds (Kim & Hannafin, 2011), as teachers may guide students to take advantage of the technology scaffolds embedded the instructional process. Teacher guidance may better help the development of students' skills and task performance in everyday classroom settings (Crawford, 2000; Zhao & Frank, 2003). Third, another interesting issue that could have received more attention in our study is the fact that experimental students worked in pairs during all the instructional process. This variable was not analysed in our study but it could be in futures studies, due to the considerable incidence of the collaborative work in the improvement of IPS skills (Lazonder, 2005; Okada et al., 1997; Teasley, 1995).

Despite the above limitations, our study showed the potential in developing students' IPS skills through the design of an embedded, structured and supported IPS instruction. We claim that this kind of educational intervention might contribute to coaching secondary students into digital competences that may allow them a better use of web information and fully participate in the global knowledge society.

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